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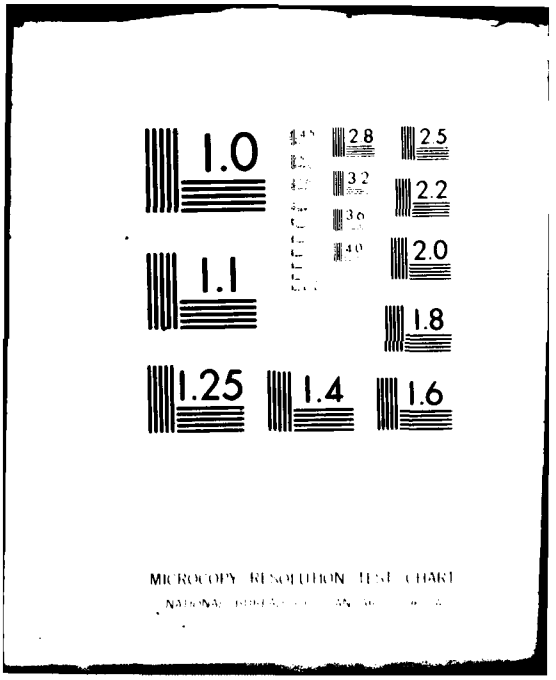
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UNIVERSITY OF WASHINGTON

COLLEGE OF ENGINEERING

Department of Electrical Engineering

Seattle, Washington 98195

SYNTHESIS OF GENERALIZED COHERENT OPTICAL PROCESSOR

by

F. Paul Carlson

U of W Technical Report No. 220

ONR Contract No. N00014-76-C-0522

Task No. NR 350-005

FINAL REPORT

1 August 1975 - 30 September 1978

August 1980

Scientific Officer

Mr. Joel Trimble

Prepared for

Office of Naval Research
Mathematical and Information Sciences Division
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ABSTRACT

This final report gives a summary of all the work completed under this contract, covering the period from August 1975 to September 1978. The work covers a broad spectrum of activities, including generalized operator theory for coherent optical processors to specific realizations of processor elements and algorithms.

The emphasis is directed towards generating new ideas to solve theoretical as well as practical problems. Success in our effort is evidenced by the list of reports and publications.

TABLE OF CONTENTS

I. Introduction

Our effort for the past three years has been centered on the following related subjects:

1. General optical processor theory
2. Adaptive optical processors
3. Application of photodichroic materials
4. Fiber optic and integrated optical switches, multiplexers, and modulators
5. Applications to high data rate ocean surveillance data reduction problems and algorithms.

Our primary effort was to concentrate on generating new ideas and formalisms for which no previous formal work had been done. Secondly, to find practical realizations and application of these ideas and methodology.

A brief description of each research area follows in this report along with a list of publications.

II. General Optical Processor Theory

This first effort concentrated on general studies of the n-plane optical processor. This entailed explorations of the 5-, 6-, and n-plane processors in terms of existence and realizability tests, and in terms of realistic information processing measures for the general ocean surveillance problem. The algebraic and algorithmic implications of this n-plane analysis approach showed the basis of a generalized optical computing theory. Our work has shown that the Fourier processor and the correlation/convolution processors are the simplest non-integral processors (2- and 3- plane processors) that arise in this n-plane formalism. The 4-plane system has led to a general description of the ambiguity function

optical processor and to an oblique to rectangular image erecting system. Although these realizations do not represent the most general realizations in a 4-plane system, existence and realization tests have been derived for the test of any 4-plane realization. The details of this work are presented in publications 1-3, 5, 7, 8, 9, 11 and 12 and presentations 1, 2 and 4.

III. Adaptive Optical Processors

Our second focus was on the general extension of the work in adaptive optical processors. Our work has shown that hybrid optical/digital adaptive systems can be synthesized for pattern recognition and detection/counting data processing problems.

Details of work accomplished are presented in publications 4 and 6 and in presentation number 3.

IV. Application of Photodichroic Materials

The third area involved the pursuit of the development of real-time, thin-film dichroic photographic film. It now seems possible to develop a reusable and modifiable film for use in optical processor interface applications. Our work with the evaporation of colored photodichroics onto appropriate substrates and with ion-implanted thin-films has shown that writeable photodichroic media can be achieved. The efficiencies are within 35% to 45% of that achievable with bulk materials. In addition the media seems stable with minimal diffusion to the film surface. From our early tests it appears that multiple implanted layers will yield the needed optical density ranges while preserving media integrity.

Details of this work are presented in publications 8 and 13.

V. Fiber Optic and Integrated Optical Switches, Multiplexes, and Modulators

A fourth area of work was on integrated optical switches, multiplexers, and modulators. It appeared that the Marcatelli technique of tuned resonator coupling could be used as either an integrated optical switch, multiplexer/demultiplexer, or modulator/demodulator system in hybrid fiber-integrated optical systems. We explored how to overcome the problems encountered by Marcatelli by using an electric field to tune the resonator length. These electric field techniques have been used by NRL and NOSC in the development of simple integrated optical phase controlled switches.

Details of this work are presented in technical reports 2 and 3.

VI. Applications to High Data Rate Ocean Surveillance Data Reduction Problems and Algorithms

We explored the application of the above optical computing theory and device realizations to the high data rate problems associated with the ocean surveillance data reduction problem. This involved specific exploration of how to best realize the ambiguity function algorithm. Several models were explored and discussed in publications 2, 3, 5, 7-12 and technical report 4.

Higher-order algorithms were explored and discussed in detail in publications 3, 5, 7-11, technical report 4, and in presentations 2-4. The higher order algorithms turned out to be particularly important in problems where library spectra or signature were to be compared and correlated simultaneously with the basic processing algorithm. In addition, higher order correlations like the ambiguity function are desirable when multi-dimension signals and tracks are compared and tested, even including multi-dimensional doppler signals.

VII. Personnel

Dr. F. Paul Carlson, Principal Investigator

Dr. John L. Bjorkstam, Co-principal Investigator

Research Assistants

Mr. R. E. Francois, Jr.	(Ph.D. 1978)
Mr. C. K. Lee	(Ph.D. 1980)
Mr. C. K. Lau	(M.S. 1976)
Mr. A. Richter	(Ph.D. expected 1981)
Mr. M. Mueller	(Ph.D. 1975)
Mr. C. T. Chang	(Ph.D. 1976)

LIST OF PUBLICATIONS ACCOMPLISHED

UNDER SUBJECT CONTRACT

Journals

1. M. R. Mueller and F. P. Carlson, "Bandlimiting effects in an optical Laplace transform computer," Appl. Opt., 14, pp. 2207-2212, September 1975.

2. M. R. Mueller and F. P. Carlson, "Apodization filtering applied to a bandlimited optical Fourier transformer," Appl. Opt., 15, pp. 690-695, March 1976.

3. F. P. Carlson and R. E. Francois, Jr., "Generalized linear processors for coherent optical computers," Proc. IEEE, 65, pp. 10-18, January 1977.

4. F. P. Carlson and C. K. Lee, "An adaptive coherent optical processor for cell recognition and counting," IEEE trans. BioMed Engr., BME-25, pp. 361-367, July 1977.

5. F. P. Carlson and R. E. Francois, Jr., "Bandlimiting Considerations in Geometrical Distortion Systems," Proc. Sym. SPIE, 83, pp. 137-145, August 1976.

6. F. P. Carlson and C. K. Lee, "Adaptive Optical/Digital Methods Applied to Biomedical Images," Proc. of First Int'l Conf. on Information Sci. and Systems, ISA, Vol. 2, pp. 530-537, Patras, Greece, August 1976.

7. F. P. Carlson and R. E. Francois, Jr., "Generalized Processors for Optical Computing," Proc. Sym. Int'l Opt. Computing Conference, IEEE 76CH1100-7C, Capri, Italy, 1976.

8. F. P. Carlson and J. L. Bjorkstam, "Real-time Re-usable Photographic Film," ONR/DARPA Proceedings, Seattle, July 1976.

9. F. P. Carlson and R. E. Francois, Jr., "System Considerations in Applying Optical Processors," Proc. Sym. SPIE, 128, pp. 296-310, 1977.

10. F. P. Carlson, "Optical Signal Processing Methods for Undersea Surveillance (S)," Editor, ONR/DARPA Proceedings, July, 1976.

11. F. P. Carlson, "Non-Acoustic ASW Review," Report of Panel for Naval Research Advisory Committee (NRAC), Editor, October 1977.

12. R. E. Francois, Jr., and F. P. Carlson, "Iterative Fourier approach for describing linear, multiple plane, coherent optical processors," Appl. Opt., 18, pp. 2775-2872, August, 1979.

13. F. P. Carlson, "A generalized approach to optical pattern recognition systems," Proc. Sym. SPIE, 201, pp. 146-155, 1979.

14. C. T. Chang and J. L. Bjorkstam, "Amplitude hologram efficiencies with arbitrary modulation depth, based upon a realistic photographic film model," JOSA, 67, pp. 1160-1164, September, 1977.

Presentations (unpublished)

1. F. P. Carlson, "Minimized four-plane processors," Proc. Sym. USNC/URSI, Bostom, Mass., 1976.

2. F. P. Carlson, "Minimized four- and five-plane processors," Proc. Sym. USNC/URSI, Stanford, 1977.

3. F. P. Carlson, "New features of adaptive optical data processors," Proc. Sym. USNC/URSI, Stanford, 1977.

4. F. P. Carlson and R. E. Francois, Jr., "Higher-Order Data Processing Algorithms Realizable in Optics," Proc. Sym. USNC/URSI, pp. 157, June, 1979.

Books

1. F. P. Carlson, Introduction to Applied Optics for Engineers, Academic Press, New York, 1977.

Technical Reports

1. F. P. Carlson and R. E. Francois, Jr., "Geometric Distortions in a Coherent Optical Processor," UW Technical Report No. 198, April 1976.

2. F. P. Carlson and A. Richter, "Guided Waves in Alkali-Halide Films," UW Technical Report No. 201, December 1976.

3. F. P. Carlson and A. Richter, "Interim Report on Guided Waves in Titanium Diffused Lithium Niobate," UW Technical Report No. 203, January 1977.

4. R. E. Francois and F. P. Carlson, "On Linear Operations Realizable in a Coherent Optical Processor," UW Technical Report No. 208, April 1978.

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Photodichroism						
Kramers Kronig relation						
Thin film deposition						
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Lens apodization						
Optocal elements: prisms						
lenses						
gratings						
effects of ionizing radiation						
Optical computers						
Coherent optics						
Ambiguity function Algorithms						
Processors						
Realizability tests						
Adaptive processing						
Multi-plane processors						
Optical switches						
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